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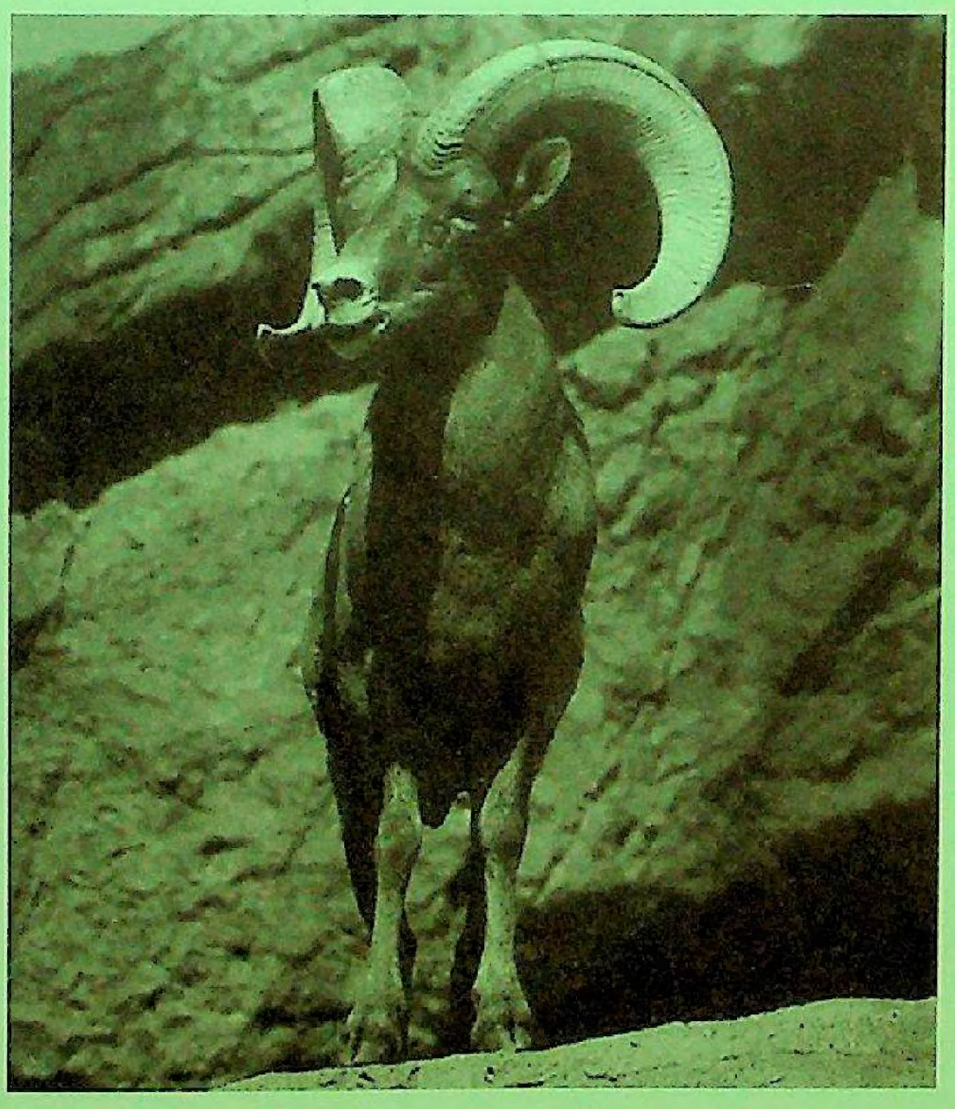

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COVER

Mountain Sheep, *Ovis canadensis*

California Fish and Game 85(4):148-160 1999

DISTRIBUTION AND INTENSITY OF HUNTING AND TRAPPING ACTIVITY IN THE EAST MOJAVE NATIONAL SCENIC AREA, CALIFORNIA

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The Mojave Desert supports a diversity of habitats and a concomitant diversity of wildlife species, many of which are of interest to hunters or have commercial value. In 1980, the East Mojave National Scenic Area (EMNSA) was delineated by the Bureau of Land Management in its California Desert Conservation Area Plan. As a result of Congressional action during October 1994, the EMNSA became the Mojave National Preserve, to be administered by the National Park Service. During 1982–1994, we quantified hunting and trapping activity in the EMNSA. The intensity of these activities varied annually, geographically, and with the species pursued. Hunting effort for Gambel's quail, *Lophortyx gambelii*, and mule deer, *Odocoileus hemionus*, has trended upward since 1990. These data provide a baseline against which future changes in land management policies and their effects on hunting and trapping activities can be evaluated.

INTRODUCTION

Southeastern California has a low-density human population, and the majority of that vast area is held in trust for the American public by the United States Government. Most of southeastern California was the subject of a massive planning effort by the United States Bureau of Land Management (BLM) during the 1970s. That planning effort resulted in establishment of the California Desert Conservation Area (CDCA) (Chambers 1995). The CDCA includes >100,000 km^2 of arid habitats consisting of portions of the Sonoran, Mojave, and Great Basin deserts.

The management plan for the CDCA (BLM[1] 1980) established 4 categories of use for public lands: 1) controlled (to be managed as nonimpairment areas or as potential wilderness areas), 2) limited (to be managed for low-intensity, carefully controlled multiple uses of resources, while ensuring that sensitive values would not

[1] BLM. 1980. The California Desert Conservation Area Management Plan. USDI Bureau of Land Management, California Desert District, Riverside, California, USA.

be significantly diminished), 3) moderate (to be managed for controlled higher intensity uses such as mining and recreation, while conserving desert resources and mitigating damage to those resources that permitted activities may cause), and 4) intensive (to be managed for concentrated use of resources to meet human needs). In short, land use categories were identified to meet conservation objectives and to provide for a diversity of recreational or commercial uses; 45 areas were preliminarily recommended for wilderness status (BLM[1] 1980). In addition, the plan informally identified a portion of the CDCA as the East Mojave National Scenic Area (EMNSA) (Chambers 1995). Essentially all of the EMNSA was within controlled, limited, or moderate categories of land use (BLM[1] 1980).

Although it originally was delimited in 1980, the >6,500-km^2 EMNSA was formally established in 1988 because of growing public interest in the eastern Mojave Desert (BLM[2] 1988). This administrative area was managed by BLM from its inception until the dissolution of the EMNSA in 1994, when the California Desert Protection Act (NPS[3] 1998) transferred management authority for the EMNSA to the United States National Park Service (NPS). As a result, the EMNSA, with slight boundary adjustments, was renamed the Mojave National Preserve (MNP). Simultaneously, 2,835 km^2 within the newly created MNP, most of which had not been recommended for inclusion in the National Wilderness System during the CDCA planning effort (BLM[1] 1980), were designated as "wilderness" (NPS[3] 1998), despite the vast network of established roads (Albright[4] 1999, Dickerson[5] 1999) and other evidence of human activity that existed throughout those areas.

Borders of the EMNSA and the MNP essentially are congruent and, with minor exceptions, these 2 areas are geographically the same. Management direction for NPS and BLM differs substantially, however. Those differences ultimately will result in a shift of management emphasis from one of dispersed recreation and multiple use (BLM[1] 1980) to one that emphasizes total protection of resources to the extent provided by the California Desert Protection Act.

Wildlife in the eastern Mojave Desert is abundant and diverse and the study area traditionally has provided extensive recreational hunting opportunities. Because of pending changes in management objectives, we investigated distribution and intensity of hunting and trapping activity in the EMNSA. Although the enabling legislation identified hunting and trapping as acceptable activities within the MNP, designation of vast areas as wilderness and the subsequent closure of many roads likely will result in decreased hunting and trapping opportunities because vehicular access will

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[2] BLM. 1988. East Mojave Scenic Area Management Plan. USDI Bureau of Land Management, Needles Resource Area, Needles, California, USA.

[3] NPS. 1998. Draft environmental impact statement and general management plan, Mojave National Preserve, California. USDI National Park Service, Barstow, California, USA.

[4] Albright, D. 1999. The fight for access. American Hunter 27(10):57-58.

[5] Dickerson, M. 1999. Golden State quail forecast. California Game and Fish Magazine 1999(10):20-23, 49.

be severely restricted (Albright[4] 1999, Dickerson[5] 1999, Bean[6] 1999, Pauli and Bleich[7] 1999). Our purpose was to quantify hunting and trapping activity in the EMNSA and to analyze it from temporal and spatial perspectives; those data can then serve as baselines against which changes in the distribution and intensity of this activity in the MNP can be measured in the future.

METHODS

Study Area

The EMNSA is located in northeastern San Bernardino County, California, and is centered (35°05'N, 115°25'W) approximately 125 km southwest of Las Vegas, Nevada (Fig. 1). It is bordered on the north by Interstate Highway 15 and Nipton Road, with an extension northward into the Clark Mountain Range; on the east by the California-Nevada border, several unnamed roads, and Goffs Road; on the south by Interstate Highway 40; and on the west by Budweiser Wash, the Union Pacific

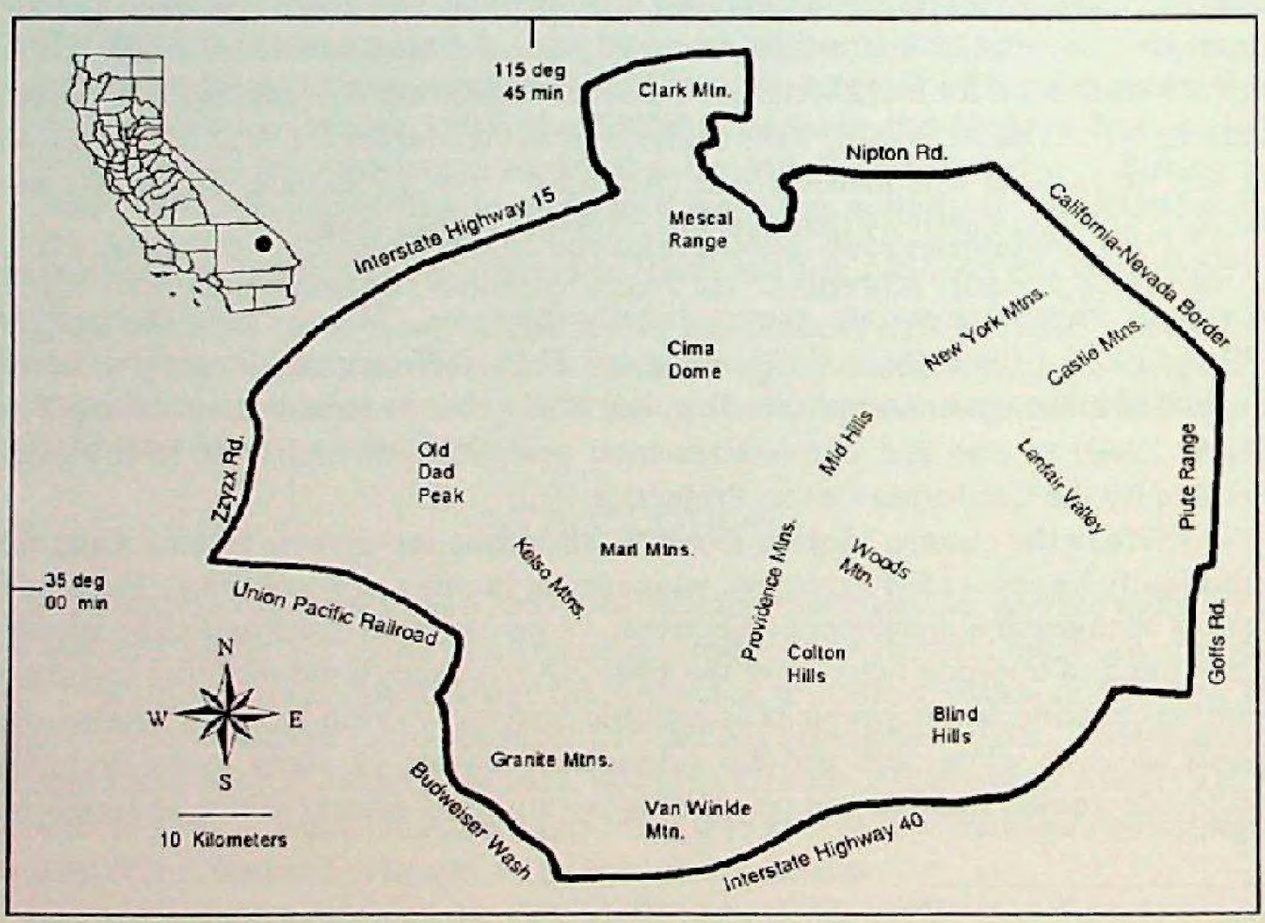

Figure 1. Map of the study area showing specific geographic locations referred to in the text and the boundary of the East Mojave National Scenic Area, San Bernardino County, California, as it existed 1980–1994.

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[6] Bean, R.A. 1999. The last stand for D-17? California Game and Fish Magazine 1999(9):24-26, 52-53.

[7] Pauli, A.M. and V.C. Bleich. 1999. Gambel's quail hunting opportunities abundant within Mojave National Preserve. Upland Game California, Fall 1999:8-9, 14.

Railroad tracks, and Zzyzx Road. This research was conducted within the EMNSA as it existed from 1980 to 1994.

The EMNSA is geologically and topographically diverse and contains numerous mountain ranges and other geological features. Most of the mountain ranges are oriented on a southwest to northeast axis and elevations range from 275 m on the western edge of the EMNSA to 2,417 m at the summit of Clark Mountain. The region includes expansive sand dunes and lava flows, limestone and granitic mountain masses, a granitic dome, and numerous extensive playas.

Annual precipitation averages about 8 cm, falling primarily as rain; about half occurs in winter and half in summer as thundershowers. Annual precipitation is highly variable and unevenly distributed geographically (Freiwald[8] 1984). In summer, daily temperatures normally exceed 38°C and winter low temperatures frequently are below freezing (Weaver et al.[9] 1969). A pronounced drought occurred in 1990, when only 3 cm of precipitation was recorded (Bleich et al. 1997).

Vegetation communities in the EMNSA are typical of those throughout the Mojave Desert. Prevalent plant communities (Mayer and Laudenslayer[10] 1988) include Desert Scrub, Alkali Desert Scrub, Desert Wash, Desert Succulent Scrub, Joshua Tree Woodland, Desert Riparian Woodland, and Pinyon-Juniper Woodland. White Fir Forest is limited to the highest elevations of the Clark and New York mountains (Paysen et al.[11] 1980, Thorne 1982) and Rupicolous Scrub is associated with limestone massifs in the study area (Martens and Baldwin[12] 1983). The amount of ephemeral vegetation in each vegetation community varies with rainfall, but annual plants can be a dominant element in the Mojave Desert during years of adequate precipitation (Beatley 1974, Bleich et al. 1997).

With the exception of the Mid Hills and the Granite, Providence, and New York mountains, water availability is limited in the study area. Many small game "guzzlers" have been constructed in the study area and provide benefits to upland game and many species of nongame wildlife (Bleich et al. 1982). Numerous natural springs and rock tanks have been physically modified and are maintained by the California

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[8] Freiwald, D.A. 1984. Groundwater resources of Lanfair and Fenner valleys and vicinity, San Bernardino County, California. USGS Water Resources Investigations Report 83-4082. U.S. Geological Survey, Washington, D.C., USA.

[9] Weaver, R.A., J.L. Mensch, and R.D. Thomas. 1969. A report on bighorn sheep in northeastern San Bernardino County, California. Final Report, Federal Aid in Wildlife Restoration Project W-51-R-14. California Department of Fish and Game, Sacramento, California, USA.

[10] Mayer, K. and W.B. Laudenslayer. 1988. A guide to wildlife habitats of California. California Department of Forestry and Fire Protection, Sacramento, California, USA.

[11] Paysen, T.E., J.A. Derby, H. Black, V.C. Bleich, and J.W. Mincks. 1980. A vegetation classification system applied to southern California. USDA Forest Service General Technical Report PSW-45. Pacific Southwest Forest and Range Experiment Station, Riverside, California, USA.

[12] Martens, S. and B. Baldwin. 1983. Vegetation and flora. Pages 3.1-3.43 *in*: B.B. Curry, editor. Old Dad-Kelso Mountains resource survey. Environmental Studies Program, University of California, Santa Barbara, California, USA.

Department of Fish and Game (CDFG) to provide water for wildlife (Bleich et al. 1982). Water sources developed by ranchers for livestock also are used by a variety of wildlife. In addition, 7 big game guzzlers (artificial water sources for large mammals) have been developed by CDFG in cooperation with BLM (3 at Old Dad Peak, 1 in the Kelso Mountains, 2 at Clark Mountain, and 1 in the Piute Range) and receive extensive use by mountain sheep, *Ovis canadensis* (Bleich[13] 1983, Bleich and Pauli 1990, Jaeger et al. 1991, Bleich et al. 1997).

Approximately 500 people permanently reside in the study area (Pauli[14] 1995). These individuals inhabit several small towns, as well as mine sites and ranches. On weekends and during holiday periods, the permanent human population is augmented by visitors from outside the area, including rockhounds, sightseers, researchers, students, photographers, bird-watchers, hunters, and trappers.

Distribution and Intensity of Hunting and Trapping Activity

We reviewed a total of 37 warden-years of daily activity reports (DARs) that included 17 geographic locations in the EMNSA (Fig. 1) during 1982–1994. We devised a relative measure of hunting or trapping intensity from these reports and termed that index the number of contacts/patrol-day-location (PDL). We pooled these data for annual hunting seasons; each season began on 1 September and extended through the following February. Hunting seasons were identified by the year in which they began.

We used data from CDFG Annual Hunter Surveys to estimate the total number of recreational hunting days for Gambel's quail, *Lophortyx gambelii*, in the EMNSA during 1983–1993. Additionally, aerial counts of vehicles have been conducted at the same locations on the opening morning of 11 mule deer, *Odocoileus hemionus*, seasons since 1971. We used vehicles tallied during these aerial surveys as an index to deer hunting intensity on opening weekends and used annual tallies of deer harvest report cards from 1955 to 1994 to index success of deer hunters.

Mountain sheep have been hunted at Old Dad Peak and in the Kelso Mountains since 1987, and in the Marl Mountains and at Clark Mountain since 1992. We compiled data on hunter effort from interviews with hunters during the mandatory mountain sheep hunter checkout process (Torres et al. 1993).

Statistical Analyses

We used analysis of variance (ANOVA) with rank-transformed data (Conover and Iman 1981) or Kruskal-Wallis tests (Zar 1984) to test for differences in hunter effort by hunting season and geographic location. We used Spearman rank correlation (Zar 1984) to evaluate the association between year and overall hunting activity, year and deer hunting intensity, and year and deer harvest.

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[13] Bleich, V.C. 1983. Big game guzzlers and mountain sheep. Outdoor California 44(6):10.

[14] Pauli, A.M. 1995. History, use, and management of harvestable species in the Mojave National Preserve. Unpublished report, Game Bird Heritage Program, California Department of Fish and Game, Sacramento, California, USA.

RESULTS

Distribution and Intensity of Total Hunting and Trapping Activity

From 1982 to 1994, hunters or trappers were contacted by wardens during 639 of 954 (67%) reported PDLs. Despite a severe drought that influenced forage availability (Bleich et al. 1997) and, in all probability, the abundance of wildlife (Pauli[14] 1995) in parts of the Mojave Desert, hunting and trapping activity (as indexed by contacts/PDL) did not exhibit a significant trend during our investigation ($r_s = 0.40$, $n = 13$, $P > 0.10$).

Using hunter-contacts/PDL as an index, overall hunting intensity varied significantly among the 17 geographic locations ($F = 5.45$; $df = 16, 908$; $P < 0.001$) (Fig. 2). Similarly, hunting intensity differed among years ($F = 7.31$; $df = 12, 941$; $P < 0.001$) (Fig. 3) when pursuit of all types of game was considered simultaneously. When we pooled the 17 locations into 5 general areas (Mid Hills, Woods Mountain, New York Mountains, Lanfair Valley, all other areas combined) based on patrol effort by game wardens, and pooled hunting seasons into 2 periods (1982–1988 and 1989–1994), a 2-way ANOVA indicated a significant effect of period ($F = 6.22$; $df = 1, 915$; $P = 0.013$) and area ($F = 9.07$; $df = 4, 915$; $P < 0.001$) on total hunter

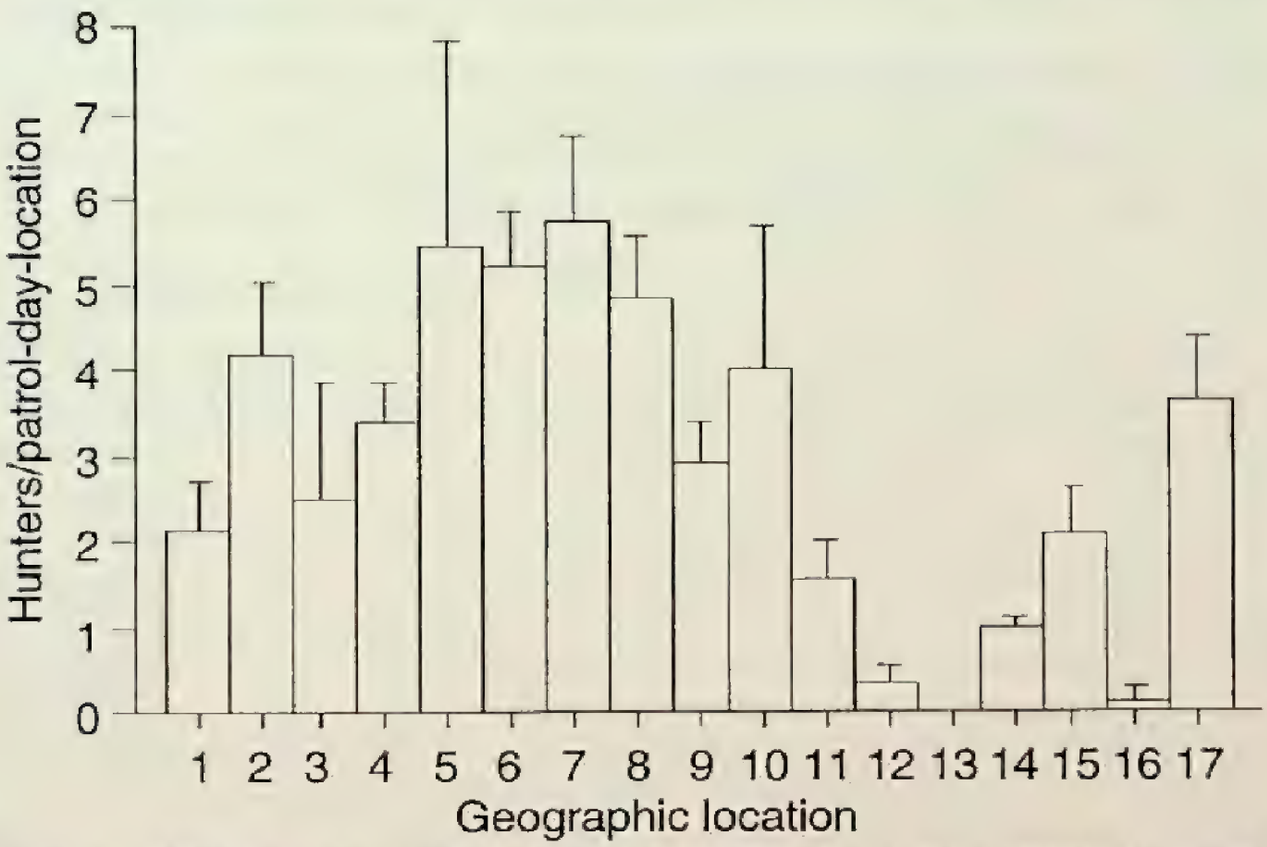

Figure 2. Mean hunting intensities (and standard errors), as indexed by hunters contacted/PDL, in specific geographic locations of the East Mojave National Scenic Area, San Bernardino County, California, 1982–1994. Numbers on the X-axis represent specific geographic locations, as follows: 1 = Granite Mountains, 2 = Van Winkle Mountain, 3 = Blind Hills, 4 = Colton Hills, 5 = Providence Mountains, 6 = Mid Hills, 7 = Woods Mountain, 8 = Lanfair Valley, 9 = New York Mountains, 10 = Piute Range, 11 = Cima Dome, 12 = Marl Mountains, 13 = Kelso Mountains, 14 = Old Dad Peak, 15 = Castle Mountains, 16 = Mescal Range, 17 = Clark Mountain.

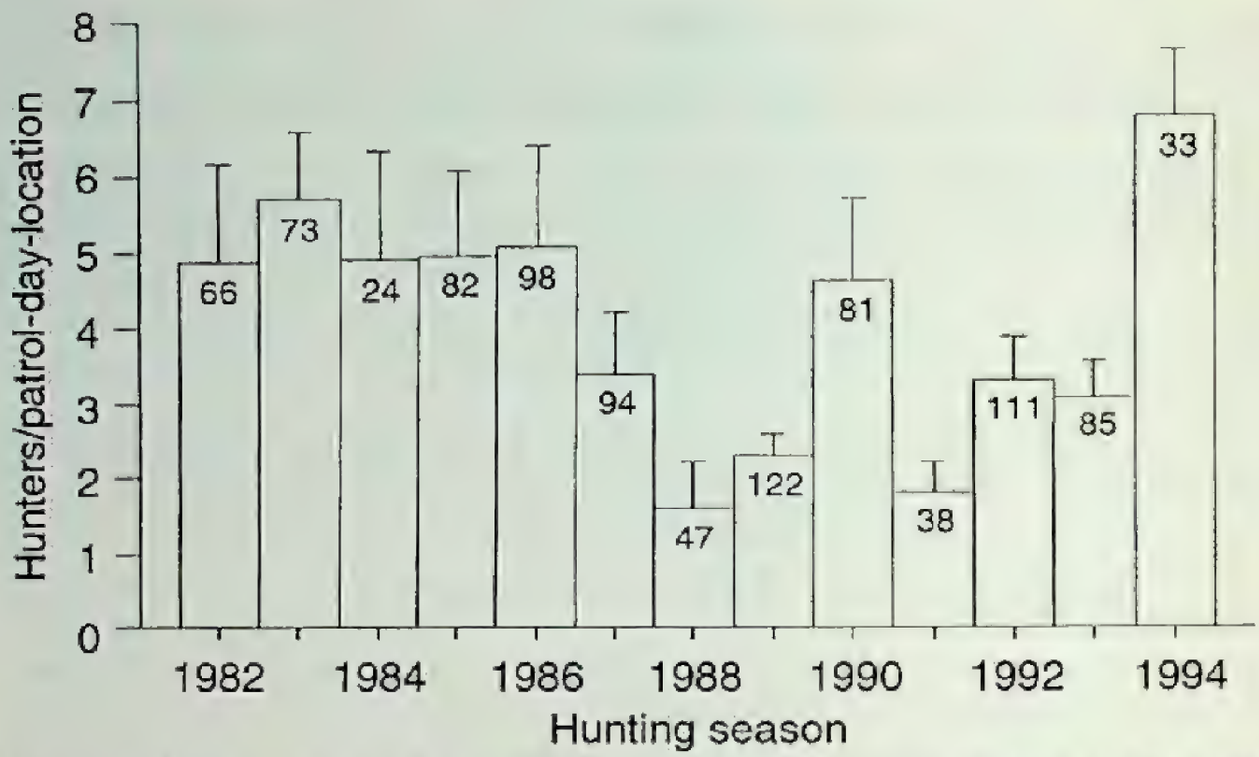

Figure 3. Mean annual hunting intensities (and standard errors), as indexed by hunters contacted/PDL, in the East Mojave National Scenic Area, San Bernardino County, California, 1982–1994. Numerals within bars indicate the number of PDLs tallied during each hunting season.

effort; the interaction term (period x area) was marginally significant ($F = 2.39$; $df = 4, 915$; $P = 0.050$), suggesting that hunter distribution may have changed between the early and late time periods. On average, hunters were contacted at a slightly lower rate during 1989–1994 (3.74 contacts/PDL) than during 1982–1988 (4.78 contacts/PDL).

Distribution and Intensity of Upland Game Hunting Activity

Using contacts/PDL as an index, there was no effect of year ($F = 1.03$; $df = 12, 309$; $P = 0.424$,) on hunting intensity when all locations used by upland game hunters were considered simultaneously. Intensity of hunting activity, however, differed significantly ($F = 1.91$; $df = 14, 307$; $P = 0.025$) (Table 1) among geographic locations used by upland game hunters within the EMNSA when all years were pooled.

Among upland game hunters, there was a significant difference in intensity among those pursuing Gambel's quail or chukar, *Alectoris chukar*; mourning doves, *Zenaidura macroura*; lagomorphs (Audubon's cottontail, *Sylvilagus audubonii*, or black-tailed jackrabbit, *Lepus californicus*); and all upland species in combination ($F = 5.91$; $df = 3, 318$; $P = 0.001$). When we divided the study into early (1982–1988) and late (1989–1994) periods, a 2-way ANOVA indicated no effect of period ($F = 1.72$; $df = 1, 314$; $P = 0.191$), but did indicate a significant effect of type of game sought ($F = 4.61$; $df = 3, 314$; $P = 0.004$) on hunter effort. The interaction term (period x quarry) was not significant ($F = 0.84$; $df = 3, 314$; $P = 0.473$). We treated subgroups of upland game hunters categorically during further analyses.

Using data obtained from warden DARs, we found that hunting intensity for quail and chukar was distributed differentially among locations used by quail and chukar

hunters within the EMNSA ($F = 1.84$; $df = 13, 198$; $P = 0.039$) (Table 1). However, the effect of year on hunting intensity for these gallinaceous birds was not significant when all locations were pooled ($F = 0.98$; $df = 11, 200$; $P = 0.464$). A 2-way ANOVA indicated no effect of period (early vs. late) ($F < 0.01$; $df = 1, 202$; $P = 0.959$), but did show a significant effect of area ($F = 3.59$; $df = 4, 202$; $P = 0.008$) on hunter effort. The interaction term (period x area) was not significant ($F = 0.06$; $df = 4, 202$; $P = 0.992$).

California Department of Fish and Game Hunter Survey data suggest that Gambel's quail hunter effort and harvest in the EMNSA varied from 1983 to 1993, despite a relatively constant number of hunters participating each year (Fig. 4). On average, an estimated 1,525 individuals pursued Gambel's quail in the EMNSA each year; total hunter-days varied from 4,700 in 1990 to >10,000 in 1993. During this period, the estimated annual quail harvest ranged from 10,700 to 26,300 (mean = 19,000) (Fig. 4).

Hunting effort for mourning doves was limited when compared to other upland game species (Table 1). Effort did not differ significantly among locations ($H = 4.87$, $df = 5$, $P = 0.432$) or among years ($H = 10.29$, $df = 6$, $P = 0.113$) in which dove hunters were contacted.

Table 1. Relative hunting intensity (as indexed by contacts/PDL) and total patrol effort recorded in each of 17 specific geographic locations of the East Mojave National Scenic Area, San Bernardino County, California, 1982–1994.

		Relative hunting intensity						
		Upland game				Furbearers		
Location	PDLs	Quail & chukar	Doves	Rabbits	Any species	Trappers	Hunters	Deer
Granite Mtns.	23	1.56	0.22	0	0.26	0.30	0	0
Van Winkle Mtn.[a]	29	3.83	0	0	0	0.24	0.10	0
Blind Hills	6	0	0	2.00	0	0.50	0	0
Colton Hills	38	1.24	0	0.95	0.76	0.21	0.10	0
Providence Mtns.	45	3.82	0.22	0.73	0.42	0.04	0.04	0.15
Mid Hills	135	1.21	0	0.67	0.24	0.25	0.03	2.81
Woods Mtn.[b]	89	3.94	0.01	0.29	0.42	0.04	0	1.02
Lanfair Valley	194	3.88	0.34	0.20	0.13	0.22	0.04	0.04
New York Mtns.	172	0.87	0.17	0.13	0.04	0.17	0.06	1.48
Piute Range	11	0.64	2.82	0	0	0.54	0	0
Cima Dome	35	0.48	0	0	0	0.34	0.14	0.60
Marl Mtns.	12	0.03	0	0	0.17	0	0	0
Kelso Mtns.	1	0	0	0	0	0	0	0
Old Dad Peak	46	0.06	0	0	0	0.09	0.17	0
Castle Mtns.[c]	39	1.77	0	0	0.13	0.18	0	0
Mescal Range	7	0	0	0	0	0	0	0.14
Clark Mtns.	43	0.23	0	0	0	0.07	0.05	3.28

[a] Includes Hidden Hills

[b] Includes Woods Wash and Watson Wash

[c] Includes Hart Mountain

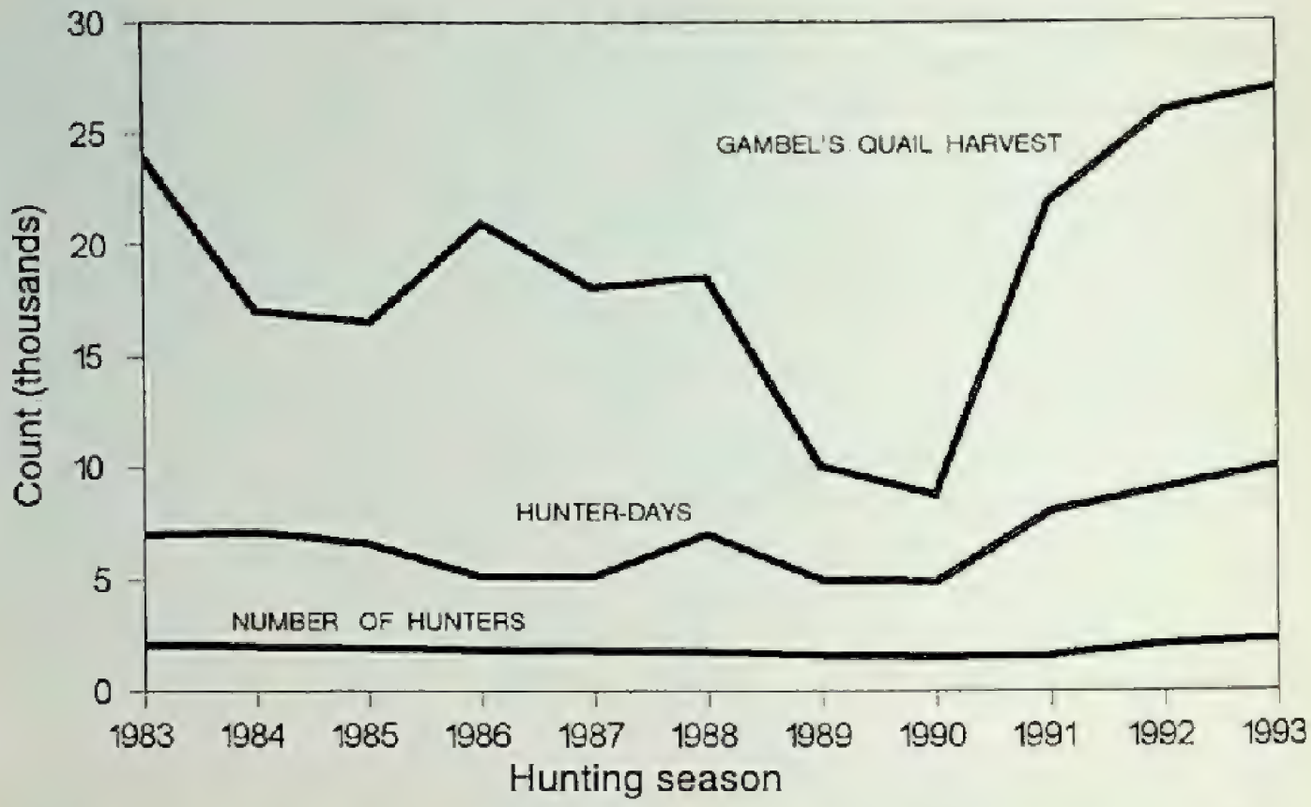

Figure 4. Estimated harvest, intensity of hunting activity, and number of individuals seeking Gambel's quail in the East Mojave National Scenic Area, San Bernardino County, California, 1983–1993.

Hunters in pursuit of lagomorphs were contacted more frequently than were dove hunters, albeit far less frequently than those seeking upland birds (Table 1). Hunting effort differed significantly among areas ($H = 12.585$, $df = 4$, $P = 0.013$), but not among years during which lagomorph hunters were contacted ($H = 3.264$, $df = 10$, $P = 0.975$).

Distribution and Intensity of Mule Deer Hunting Activity

Prior to 1991, the number of hunters that could pursue mule deer in the eastern Mojave Desert was not limited. In 1991, deer zone D-17 was created and a ceiling of 500 deer tags was established for the eastern Mojave Desert. Prior to 1991, aerial counts of deer hunter vehicles on opening day fluctuated greatly (Fig. 5), likely because hunters could pursue deer throughout a greater proportion of California and had the option of hunting in the eastern Mojave Desert as well as other parts of the state. During 1991–1994, deer hunting intensity, as indexed by opening day car counts (Fig. 5), increased each year ($r_s = 1.00$, $n = 4$, $P = 0.10$). Since 1991, tag returns have indicated that an average of 44% of deer harvested in zone D-17 have been taken on opening weekend.

Using daily activity reports as a 2nd measure, deer hunting intensity did not differ among years ($F = 1.34$; $df = 11, 128$; $P = 0.208$) or among the geographic locations in which deer hunters were contacted ($F = 1.72$; $df = 7, 131$; $P = 0.122$,) during 1982–1994 (Table 1). Nevertheless, deer tag returns from 1955 to 1994 (Fig. 6)

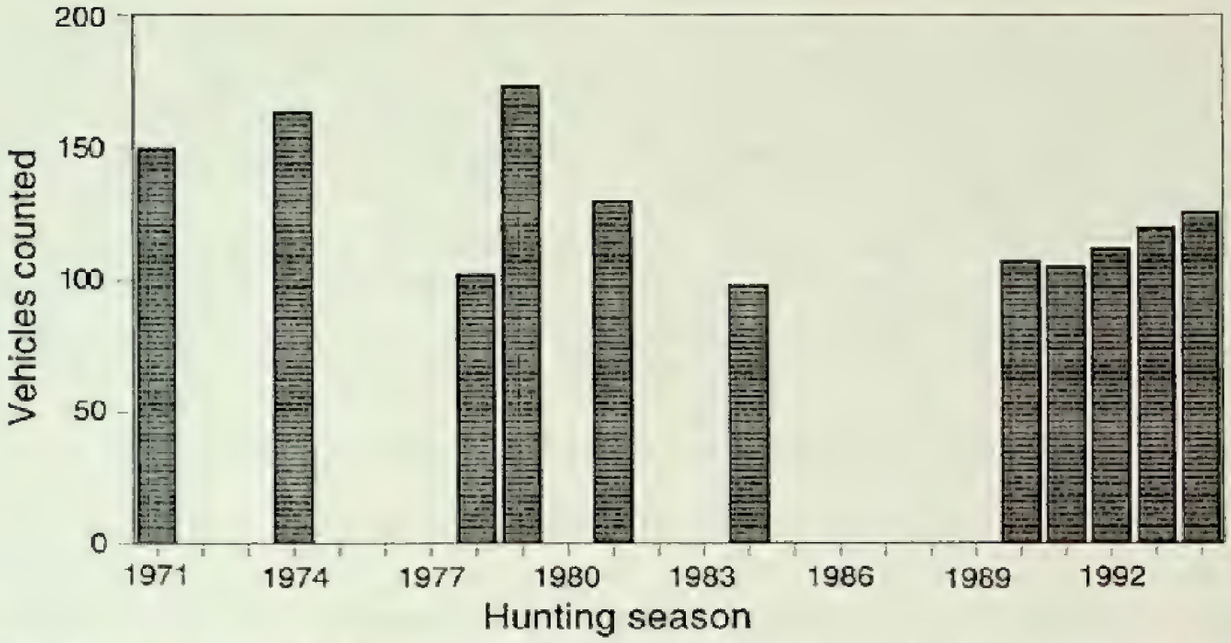

Figure 5. Intensity of mule deer hunting activity on opening day, as indexed by car counts, in the East Mojave National Scenic Area, San Bernardino County, California, 1971–1994.

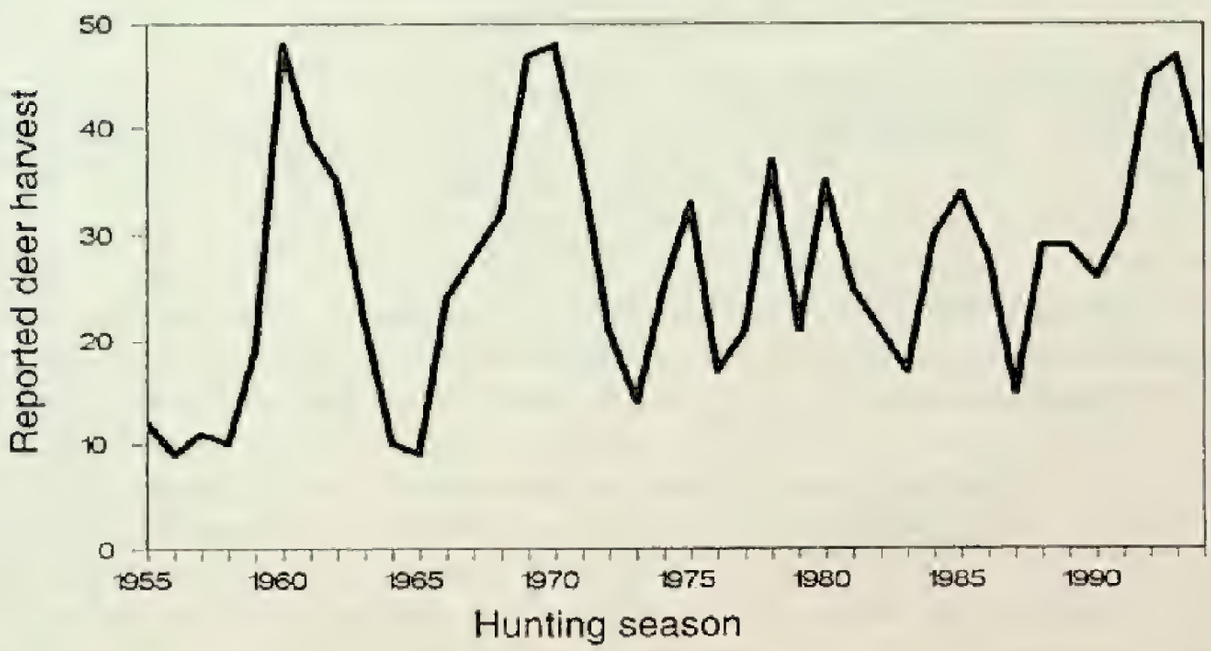

Figure 6. Harvest of mule deer, as determined from mail-in report cards, in the East Mojave National Scenic Area, San Bernardino County, California, 1955–1994.

indicate a significant positive relationship between deer harvest and successive hunting seasons ($r_s = 0.338$, n = 40, $P < 0.05$), despite a maximum of 500 hunters each season beginning in 1991.

Distribution and Intensity of Furbearer Trapping or Hunting Activity

When all locations were pooled, trapping pressure (as indexed by trapper contacts/PDL) did not differ significantly among years ($F = 1.15$; df = 10, 124; $P = 0.332$) during which trappers were contacted. Similarly, trapping pressure did

not differ among locations ($F = 0.95$; $df = 13, 93$; $P = 0.502$) when annual data were considered simultaneously (Table 1). Trapper contacts/PDL were low, because trappers distributed their efforts over large areas and, in general, traplines did not overlap. Nonetheless, trapping has been an ongoing recreational and commercial activity within the EMNSA for many years.

Contacts with individuals hunting furbearers were limited when compared with those hunting other game animals. Kruskal-Wallis tests revealed no significant difference in intensity of furbearer hunting either among years ($H = 6.80$, $df = 7$, $P = 0.450$) or locations ($H = 5.37$, $df = 8$, $P = 0.718$) (Table 1) in which contacts were made.

Distribution and Intensity of Mountain Sheep Hunting Activity

During 1987–1992, 46 individuals hunted mountain sheep in the study area (Torres et al. 1993). During that period, hunters expended 245 days of effort (mean = 5.3 days/hunter). When total size of the hunting party was considered, 665 days were expended hunting mountain sheep (mean = 14.5 days/hunter). During 1987–1992, hunter success was 100% and 46 mountain sheep were harvested.

DISCUSSION

Hunting activity, as indexed both by warden contacts/PDL and the CDFG Annual Hunter Survey, was high and relatively constant during 1982–1994, despite major fluctuations in the availability of upland game (Pauli[14] 1995). The eastern Mojave Desert and, more specifically, the EMNSA, is renowned for its high-quality habitat for Gambel's quail (Pauli and Bleich[7] 1999) and it is likely that hunters pursued these gamebirds with little regard for effects of annual precipitation and its impact on hunter success (Pauli and Bleich[7] 1999). Hunters seeking gallinaceous birds also selected specific locations in which to concentrate their efforts (Table 1), likely a function of good access and habitat, high past hunter success, and the general availability of these highly prized gamebirds. Harvest of Gambel's quail and chukar fluctuated greatly during the 1980s and early 1990s, but paralleled years of above-average production (Pauli[14] 1995). During the 1990s, hunter-days of effort by quail hunters have increased (Fig. 4) despite severe drought conditions early in that decade (Pauli[14] 1995). The number of quail hunter-days reflected the importance of the EMNSA for this type of recreation and the interest among southern California hunters in this game bird.

Dove hunters were not contacted frequently in the EMNSA, but the area provided hunting opportunities for those wanting to a[illegible]rowds associated with more popular areas in southern California. The low rat[illegible] contact likely was a function of the short hunting season, the cool temperatures in this high desert area that result in low dove densities, and wardens concentrating their patrol efforts in more heavily used areas (Pauli[14] 1995).

The EMNSA also provided many opportu[illegible] those in pursuit of lagomorphs and hunting effort for these game mammals rem[illegible] consistent. The area supports excellent habitat for both cottontail rabbits and jackrabbits, especially during years

of adequate precipitation. During 1982–1994, hunters took advantage of existing, well-traveled roads in suitable habitat in the EMNSA to pursue these mammals.

Since deer zone D-17 was established in 1991, opening day aerial car counts have risen steadily as increasing numbers of hunters have learned that deer hunting in the eastern Mojave Desert is a high-quality recreational experience and that hunter success on opening weekend is high. Moreover, success of deer hunters has increased over time, as more hunters have become familiar with the area.

Trapper contacts/PDL were low, but trapping was a recurring and, presumably, popular activity in the EMNSA. With declining fur prices, it would be expected that trapping activity would be lower recently than in the past; nonetheless, trapper contacts/PDL have not differed significantly over time. Road closures associated with newly designated wilderness areas will have a serious detrimental effect on access for trappers. Typically, trappers work alone over large areas and need access away from primary roads to be successful.

Rates of contact with individuals hunting furbearers in the EMNSA were low during 1982–1994, but remained constant over that period. Furbearer hunters contacted/PDL were similar among locations of highest use within the EMNSA and these hunters distributed themselves throughout most of the study area (Table 1); this may, in part, explain why contacts were limited.

Mountain sheep have been legal game in California only since 1987 and 2 of the hunt zones are located in the EMNSA. These 2 zones have produced the majority of the mountain sheep harvested in California.

SUMMARY

The EMNSA provided a unique and high-quality hunting experience in a remote setting for harvestable wildlife available there. Hunters distributed themselves differentially within the EMNSA, as well as by hunting season, depending on the availability of the species they were pursuing. Despite a severe drought that influenced forage availability and abundance of wildlife in the eastern Mojave Desert (Pauli[14] 1995), hunter effort did not decline significantly over the years for which records were available.

Our purpose was to describe the distribution and intensity of hunting and trapping activity in the EMNSA prior to establishment of the MNP. These data can be used to compare changes in hunter distribution, access, and success that may result from the differing management philosophies of BLM and NPS and associated new regulations. Our results quantified the importance of various parts of the EMNSA for those pursuing the harvestable species found there. During our study, there were no permanent road closures in the EMNSA; hunters and other recreationists had virtually unlimited access to the entire area as long as they restricted their travel to existing roads and designated washes (BLM[1] 1980). With the establishment of expansive areas of wilderness and associated road closures, distribution and intensity of hunting activities, as well as hunter success, likely will change substantially in the future (Bean[4] 1999). These predictions can be treated as hypotheses and are testable by recording future use by hunters and trappers in the MNP and comparing those results to data reported here.

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JUVENILE DELTA SMELT USE OF SHALLOW-WATER AND CHANNEL HABITATS IN CALIFORNIA'S SACRAMENTO-SAN JOAQUIN ESTUARY

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Juvenile delta smelt, *Hypomesus transpacificus*, densities were significantly greater in shallow water in Honker Bay and Sherman Lake than in adjacent channels in 1993, indicating that they used shallow areas in bay and flooded island environments as nursery habitats. Densities and lengths were significantly greater on high than low tides in shallow water in Honker Bay, but not in the adjacent channel, suggesting that delta smelt moved tidally between Honker and Grizzly bays. Delta smelt densities did not differ between shallow water and channels in the riverine environments of Montezuma Slough, the lower San Joaquin River, and Cache Slough, presumably because shallow areas were smaller and no embayments existed to retain delta smelt. Delta smelt may be larger in shallow water in Honker Bay and Sherman Lake because 1) fish in shallow water were older and consequently larger or 2) residence time was longer and foraging success was better, resulting in increased growth rates. Availability of shallow habitats to delta smelt increases in high-outflow years when hydrodynamic transport locates the delta smelt population downstream in Suisun, Grizzly, and Honker bays.

INTRODUCTION

The delta smelt, *Hypomesus transpacificus*, is a small planktivorous fish endemic to California's Sacramento-San Joaquin Estuary, where it ranges from San Pablo Bay upstream at least as far as the confluence of the American and Sacramento rivers and to Mossdale on the San Joaquin River (Moyle 1976). It is found from freshwater to 10‰ salinity, but is most abundant in brackish water near the 2‰ isohaline (Moyle 1976, Moyle et al. 1992). Delta smelt spawn from February to May in the lower Sacramento and San Joaquin rivers, including Cache Slough, and most larvae are carried downstream to the 2‰ isohaline, although some larvae remain upstream. Depending on river outflow, the 2‰ isohaline moves between different environments, including bays, flooded islands, and river channels (Moyle et al. 1992). Consequently, the characteristics of delta smelt nursery habitat change between dry and wet years (Moyle et al. 1992). In low-outflow years, most juvenile delta smelt inhabit channelized riverine environments close to upstream spawning areas in the lower Sacramento and San Joaquin rivers and Cache Slough. In high-outflow years, many

juveniles are transported downstream from riverine environments to Suisun, Grizzly, and Honker bays.

Delta smelt populations declined in the mid-1980s and remained low thereafter, resulting in federal and state listing as a threatened species in 1993. Moyle et al. (1992) listed the causes of the decline as 1) drought conditions during the mid-1980s which relocated delta smelt from highly productive shallow habitats in Suisun, Grizzly, and Honker bays upstream to less productive and deeper river channel habitats and 2) high mortality rates due to entrainment by the State Water Project and the Central Valley Project in the south delta where water is diverted into the California Aqueduct and the Delta-Mendota Canal for municipal and agricultural use. Moyle et al. (1992) hypothesized that delta smelt sustain high populations in high-outflow years when their preferred salinities are located in Suisun Bay due to increased shallow-water habitat area. They supported their hypothesis by comparing shoal and channel delta smelt catches by the California Department of Fish and Game (CDFG) midwater trawl survey (MWT). Sixty-two percent of MWT delta smelt catch occurred at 3 stations <4 m deep in Suisun Bay; the remaining 38% was at 6 deep channel stations.

The objective of this study was to compare juvenile delta smelt use of shallow-water habitat in bay, flooded island, and riverine environments with adjacent channels to identify potential nursery habitats. Length distributions; water quality variables, including temperature and salinity; and tidal stage were also analyzed relative to use of these habitats. Habitat characteristics of bay and riverine environments were also contrasted.

METHODS

A 31.5 x 6.1-m miniature purse seine with 1.6-mm stretch mesh was used to capture juvenile delta smelt because it reduces net avoidance common to towed nets. Similar purse seine designs have effectively sampled postlarval northern anchovies, *Engraulis mordax* (Murphy and Clutter 1972). The purse seine was deployed off the bow of a 7-m boat, while backing in a circle at a speed of 1–1.5 m/s. Once deployed, the 2 ends were joined and the bottom of the net was pursed to form a bag. An optimal purse seine set sampled 471 m^3, although water currents and wind conditions made sets less than optimal. Seine sets per station varied from 1 to 4, depending on weather.

Five areas were sampled monthly during May, June, and July 1993, a high-outflow year. Shallow-water (≤4 m deep) and adjacent channel (>4 m deep) sites were paired. Sampling occurred in Honker Bay and adjacent channel stations in the Suisun Bay channel, Sherman Lake and adjacent channel stations in the Sacramento and San Joaquin rivers, Montezuma Slough, the lower San Joaquin River, and Cache Slough (Fig. 1). Honker Bay is a shallow bay and Sherman Lake is a flooded island. Montezuma Slough, the lower San Joaquin River, and Cache Slough (MSJC) are riverine environments. Shallow-water sites and channels were sampled equally, although the number of stations sampled per area was sometimes limited by inclement weather.

All fishes collected were identified and fork length (FL) measured to the nearest millimeter. Fish >100 mm were immediately released, but all fish <100 mm were

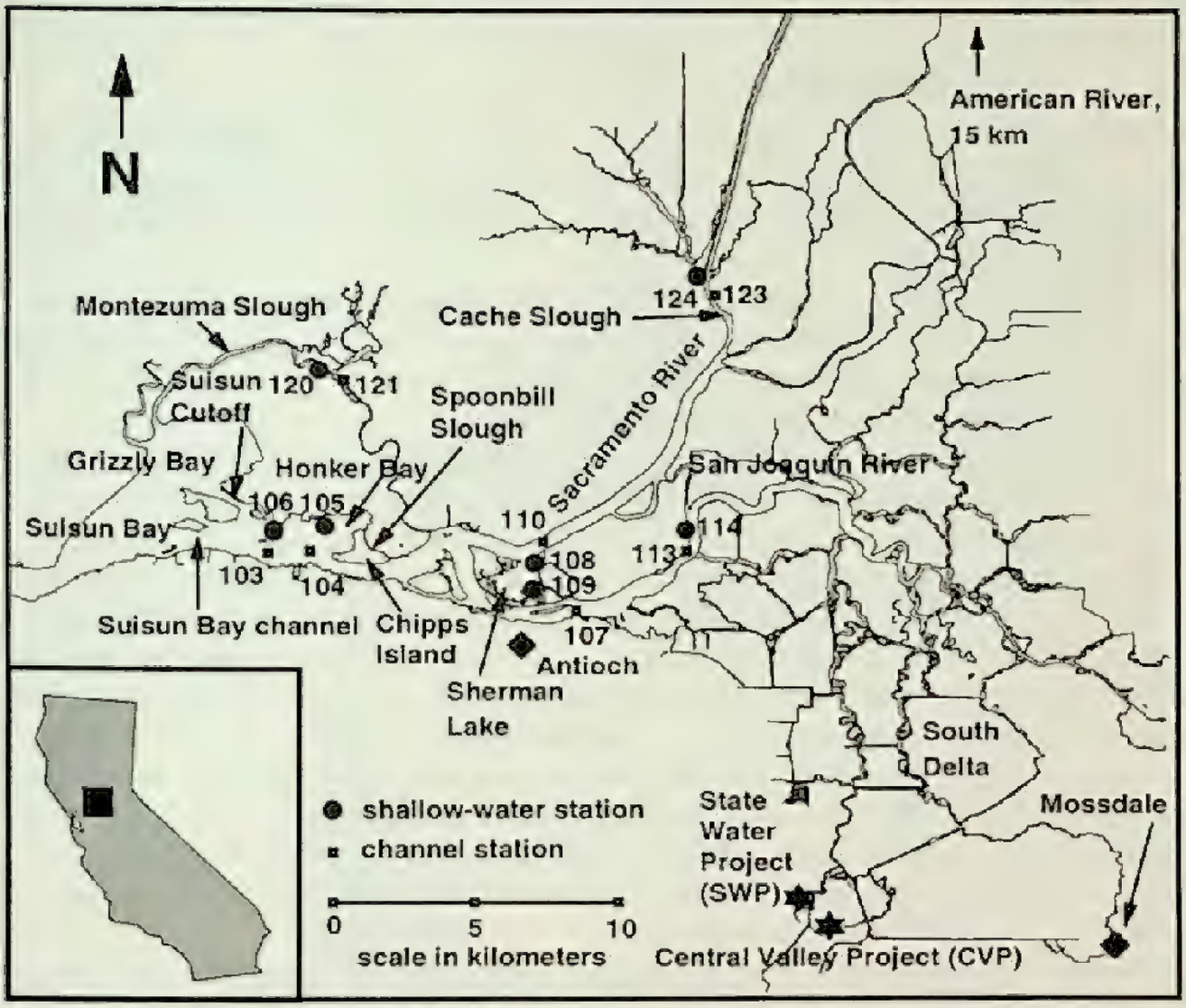

Figure 1. Delta smelt purse-seining stations in the Sacramento-San Joaquin Estuary.

preserved in sodium borate-buffered 10% formalin and returned to the laboratory for identification. Surface water temperature (°C) and electrical conductivity (EC, mS/cm) were recorded. Tidal stage and water depth were also recorded.

Delta smelt density was computed as the number of delta smelt per 1000 m^3 of purse seine volume. Seine volume was recomputed when water depth was less than seine depth. No attempt was made to adjust seine volume for sub-optimal sets.

Differences in mean delta smelt density and fork length, temperature, and EC between shallow-water and channel habitats were tested separately for each area sampled. Differences in mean delta smelt density and fork length between high (3 hours before and after high tide) and low tides (3 hours before and after low tide) were also tested for each sampling area. Density and length data from individual areas in MSJC were pooled to increase sample size if shallow water vs channel comparisons indicated that differences were not significant. Before comparisons, normality was tested with a Kolmogorov-Smirnov test. If log transformation did not normalize data, a nonparametric Mann-Whitney test was used. A t-test was used for normally distributed data. The significance level was 0.05. Statistical analyses were limited to juveniles and samples where catch was >0.

RESULTS

A total of 893 juvenile delta smelt (18–49 mm FL) was caught from May to July in 180 purse seine sets. Mean delta smelt density was highest in Honker Bay (36.9/1000 m^3), followed by Sherman Lake (28.5/1000 m^3); density was lowest in MSJC (6.2/1000 m^3).

Mean delta smelt densities were significantly greater in shallow water in Honker Bay ($U = 278.0$, $df = 1$, $P < 0.01$) and Sherman Lake ($U = 190.0$, $df = 1$, $P < 0.01$) than in adjacent channels, but not in MSJC ($U = 1288.0$, $df = 1$, $P = 0.15$) or any of its individual areas (all $P > 0.05$) (Table 1).

Delta smelt mean lengths also were significantly greater in shallow water in Honker Bay ($U = 12319.0$, $df = 1$, $P < 0.001$) and Sherman Lake ($t = 2.44$, $df = 21$, $P < 0.01$) than in adjacent channels, but in Cache Slough lengths were greater in the adjacent channel than in shallow water ($U = 1126.0$, $df = 1$, $P < 0.001$) (Table 1). Delta smelt mean lengths were not significantly different between shallow-water and channel areas in Montezuma Slough ($t = -0.96$, $df = 30$, $P = 0.35$). In the lower San Joaquin River, lengths could not be compared between shallow water and the adjacent channel because no delta smelt were caught in shallow water (Table 1).

Length frequencies for Sherman Lake and adjacent channels and Montezuma Slough were normally distributed, but length frequencies for Honker Bay and adjacent channels and Cache Slough were not. The length frequency for Honker Bay was negatively skewed by larger fish and the length frequency for Cache Slough was positively skewed by smaller fish (Fig. 2).

Surface temperature was not significantly different between shallow water and channels in any of the sampling areas (all $P > 0.05$) (Table 1). Surface EC was

Table 1. Comparison of mean shallow-water and channel delta smelt density and fork length, water temperature, and EC separately for each sampling area. Standard errors are in parentheses. $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

	Bay	Flooded island	Riverine			
	Honker Bay	Sherman Lake	MSJC	Cache Slough	San Joaquin River	Montezuma Slough
Density (no./1000 m^3)						
Shallow	71.1(29.1)**	46.9(9.0)**	6.8(3.8)	16.9(11.3)	0.0(0.0)	2.5(0.8)
Channel	5.7(2.7)	3.1(1.2)	5.6(1.7)	4.3(1.4)	1.3(0.8)	9.8(4.2)
Length (mm)						
Shallow	41.4(0.3)***	32.1(0.6)**		26.7(0.7)	No fish	29.7(1.1)
Channel	37.9(0.8)	27.7(1.7)		32.7(1.7)***	30.0(2.0)	30.9(0.5)
Temperature (°C)						
Shallow	20.0(0.6)	19.4(0.2)		19.6(0.3)	22.2(0.2)	20.0(0.3)
Channel	20.5(0.5)	19.3(0.4)		19.3(0.3)	21.8(0.1)	20.5(0.2)
EC (mS/cm)						
Shallow	1472.8(174.1)	488.9(78.3)*		237.7(14.4)*	176.0(6.5)	1600.3(97.4)
Channel	1497.6(215.4)	241.4(36.4)		182.0(14.3)	197.5(14.2)	1757.5(146.6)

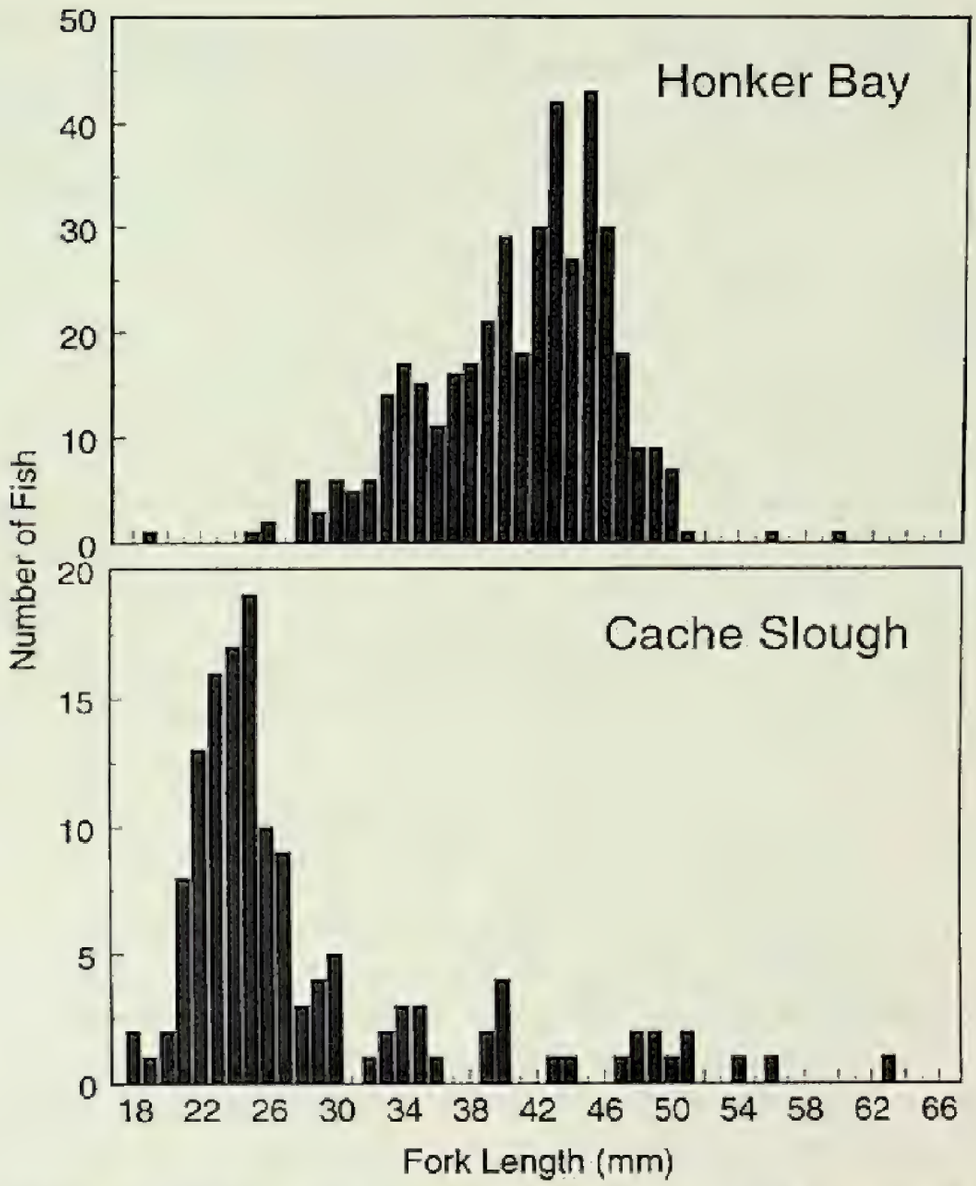

Figure 2. Length frequencies of delta smelt in Honker Bay and adjacent channels and Cache Slough. The length frequency for Honker Bay was negatively skewed by larger fish and the length frequency for Cache Slough was positively skewed by smaller fish.

significantly greater in shallow areas than in adjacent channels at Sherman Lake ($U = 169.0$, $df = 1$, $P < 0.05$) and Cache Slough ($U = 378.0$, $df = 1$, $P < 0.05$), but no significant differences were detected at the other areas (all $P > 0.05$). Surface temperature and EC for individual areas in MSJC were not pooled because of the distance between areas.

Mean delta smelt densities were significantly greater at high tide than at low tide in shallow water in Honker Bay ($U = 64$, $df = 1$, $P < 0.01$) and Sherman Lake ($U = 56$, $df = 1$, $P < 0.01$) (Table 2). Density differences associated with tidal stages were not statistically significant at shallow-water MSJC sites or any channel sites (all $P > 0.05$). As the channels adjacent to Sherman Lake were not sampled at low tide and some individual sites at MSJC were not sampled on either tide, no comparisons of delta smelt density at different tidal stages were possible at these 2 locations.

Delta smelt mean lengths were significantly greater at high tide than at low tide in shallow water in Honker Bay ($U = 1321.5$, $df = 1$, $P < 0.001$) and MSJC ($U = 343.0$,

Table 2. Comparison of high and low tide mean shallow-water and channel delta smelt density and fork length separately for sampling areas. Standard errors are in parentheses. *P<0.05, **P<0.01, ***P<0.001.

	Bay	Flooded Island	Riverine
	Honker Bay	Sherman Lake	Combined (MSJC)
Density (No./1000 m³)			
Shallow			
High	288.5(78.9)**	60.0(8.6)**	2.6(0.6)
Low	17.5(6.9)	0.0(0.0)	11.9(8.4)
Channel			
High	6.1((3.5)	3.1(1.2)	7.2(2.8)
Low	5.8(3.3)	No sample	3.2(0.9)
Length (mm)			
Shallow			
High	43.1(0.2)***	32.1(1.2)	36.3(2.1)***
Low	35.2(1.0)	No fish	25.2(0.4)
Channel			
High	40.3(1.7)	27.7(1.7)	34.7(1.7)*
Low	38.7(1.0)	No sample	30.2(0.5)

df = 1, P <0.001) and in channels in MSJC (t = –2.48, df = 34, P < 0.05) (Table 2). Delta smelt in the channels adjacent to Honker Bay showed no tidal-associated differences in length (U = 109.5, df = 1, P = 0.43). As the channels adjacent to Sherman Lake were not sampled at low tide and some individual sites at MSJC were not sampled on either tide, no comparisons of delta smelt density at different tidal stages were possible at these 2 locations.

DISCUSSION

The difference in delta smelt use of shallow water between bay (Honker Bay), flooded island (Sherman Lake), and riverine (MSJC) environments may best be explained by tidal flux and flow patterns being modified by geomorphological features (Weinstein et al. 1980, Miller 1988). The greater mean density and length of delta smelt in shallow Honker Bay than in the adjacent Suisun Bay channel and the greater mean density and length at high than low tide in Honker Bay, but not the channel, suggest that delta smelt moved in and out of Honker Bay with the tide, but not from the Suisun Bay channel. Hydrodynamics studies of this area have found that Honker Bay fills and drains through Suisun Cutoff (from and to Grizzly Bay) and that water in Honker Bay on an ebb tide is replaced with water from the lower Sacramento and San Joaquin rivers through Spoonbill Slough and around the tip of Chipps Island (J. Burau, U.S. Geological Survey, personal communication). Also, the water mass in the adjacent Suisun Bay channel moves upstream and downstream with the tide in the channel and little exchange occurs with Honker Bay (J. Burau, personal communication). Thus, delta smelt in Honker Bay likely move with the ebb tide through Suisun Cutoff

into Grizzly Bay and are carried back into Honker Bay with the flood tide. This explains why the large concentration of delta smelt sampled at high tide in Honker Bay was not found there or in the adjacent channel at low tide. Higher densities of delta smelt in Honker Bay may be related to the geomorphology of the bay, so that more fish come into the bay from upstream on the ebb tide than leave it with the flood tide. Thus, delta smelt are "trapped" in Honker Bay.

To further investigate the hypothesis that high densities of delta smelt are exchanged between Honker and Grizzly bays with the tide, delta smelt abundance data from the 1993 summer townet survey, designed to measure annual delta smelt and striped bass abundance indices in June and July (Stevens 1977; CDFG, unpublished data), were examined. Townet sampling in Honker and Grizzly bays in 1993 always occurred at low tide. Townet estimates of delta smelt density at low tide in Grizzly Bay were high (mean catch/tow = 11.2, SE = 4.6), whereas delta smelt density estimates in Honker Bay at the same tidal stage were low (mean catch/tow = 3.0, SE = 1.6). This supports the hypothesis that water with high delta smelt density moves with the ebb tide into Grizzly Bay and the previously described hydrodynamic studies indicate that much of that water flows back into Honker Bay with the flood tide.

Delta smelt were likely transported into Sherman Lake from the Sacramento and San Joaquin rivers by the flood tide and became concentrated there in higher densities by the enclosure of the breached island; some were transported out of the lake with the ebb tide. However, drifter studies from this area have shown complex flow patterns between Sacramento and San Joaquin rivers and Sherman Lake (J. Burau, personal communication) and, consequently, it would be difficult to track fish movement without simultaneous hydrodynamic studies.

These results are consistent with other studies that have shown that estuarine fishes, particularly juveniles, commonly use tidal flux to move between habitats (Miller and Dunn 1980). Flood tides transported spot, *Leiostomus xanthurus*, and flounders, *Paralichthys* spp., to nursery areas in tidal creeks and over shoals in the Cape Fear Estuary, North Carolina (Weinstein et al. 1980). Pacific coast fishes, including chinook salmon, *Oncorhynchus tshawytscha*, and chum salmon, *O. keta*, also use flood tides to move to nursery areas (Healey 1982).

In the riverine environment, densities were not significantly different between shallow water and channels. I hypothesize that delta smelt move with tides in the channel and across shallow areas, and are not retained in shallow water due to the lack of embayments. Also, shallow areas in Cache Slough, Montezuma Slough, and the San Joaquin River are considerably smaller than in Honker Bay or Sherman Lake, which could affect retention rates of fish.

Temperature and salinity had no apparent effect on use of shallow and deep water by delta smelt as values were within tolerance limits and, except for EC in Sherman Lake and Cache Slough, were not significantly different between shallow-water and channel sites.

Delta smelt were larger in shallow water in Honker Bay and Sherman Lake than in adjacent channels, but were larger in the channel than shallow areas in Cache

Slough. Delta smelt in the shallow water of Honker Bay and Sherman Lake may be larger than in the channels because 1) entrapped fish may stay longer in shallow-water areas and consequently be older and larger or 2) fish in shallow water had a more abundant food supply, resulting in greater growth. Grimaldo et al.[1] (1998) reported that delta smelt in Suisun Bay in 1996 were older and larger than individuals in the Sacramento and San Joaquin rivers. Moyle et al. (1992) hypothesized that delta smelt growth rates are higher in Suisun Bay than the Sacramento and San Joaquin rivers due to the use of highly productive shallow-water areas resulting in increased feeding. Foraging success (percent stomachs with food) for 25-mm delta smelt in 1995 and 1996 was higher in shallow water in Grizzly and Honker bays than in the Suisun Bay channel (Lott[2]1998). Future studies will examine age structure of delta smelt as an aid in understanding age and growth relative to area and chemical-physical parameters.

The larger size of delta smelt in the channel than in shallow water in Cache Slough is difficult to explain. Larger delta smelt migrating downstream from their early nursery area in the Cache Slough region in June and July may have increased mean size in the channels. Larger delta smelt downstream in Honker Bay are consistent with this explanation.

A significant increase in the availability of shallow habitats occurs in high-outflow years when the population is located in the Suisun Bay area (including Grizzly and Honker bays). Some estuarine species increase in high-outflow years due to a greater area of nursery habitat and larger populations of zooplankton available for forage (Sutcliffe 1973). Only 33% of potential delta smelt nursery habitat, mostly located in channelized riverine environments, is available during a typical low-outflow year (Moyle et al. 1992; CDFG, unpublished data). Thus, a significant relationship exists between the number of days the 2‰ isohaline is located in Suisun Bay from February through June and delta smelt abundance in the fall (Herbold[3] 1994). In 1993, the 2‰ isohaline was located in Suisun Bay during the entire period from February through June, resulting in the 6th highest delta smelt abundance observed during 1967–1993.

In conclusion, shallow-water areas in Honker Bay and Sherman Lake are important delta smelt nursery habitats. Delta smelt were larger in Honker Bay and Sherman Lake than adjacent channels, although it is uncertain if they were older fish or had greater growth rates. Delta smelt use of shallow-water nursery habitats in Montezuma Slough, the San Joaquin River, and Cache Slough was not as apparent as in Honker Bay and Sherman Lake.

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DIVER DISTURBANCE IN KELP FORESTS

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Recreational SCUBA diving has greatly increased in the past 20 years and has potential to cause significant disturbances to subtidal reefs. While diver disturbance on coral reefs has been assessed in a number of studies, disturbances in temperate kelp forests have not been previously examined. We estimated diver disturbance in southern Monterey Bay giant kelp, *Macrocystis pyrifera*, forests by following 42 divers in summer 1997 and recording their activity. During a 0.5 hour dive, the average diver contacted the bottom 43 times, touched 4 animals, and detached 2 algal blades. An estimated 65,000 diver-days are spent in these kelp forests every year, resulting in a potential loss of 130,000 algal blades and considerable benthic disturbances. The effects of these impacts and mitigation for them should be considered in proposals to establish and manage marine protected areas.

INTRODUCTION

With increased human population growth, and increased interest in and access to the shore, the potential for damage to the marine environment from recreational activities has increased. The most well-documented consequences of such activities are trampling on temperate shores (Beauchamp and Gowing 1982, Brosnan and Crumrine 1994) and coral reefs (Kay and Liddle 1987, Hawkins and Roberts 1993) and diver disturbance to coral reefs (Talge 1990, Hawkins and Roberts 1992, Rouphael and Inglis 1997). Much less is known about the effects of recreational diving activities on temperate subtidal reefs. In 1996, 728,295 divers were certified by the Professional Association of Diving Instructors (PADI), which alone certified over 100,000 SCUBA divers per year during the 1980s and over 400,000 per year since 1990 (PADI[1] 1997). The diving activity resulting from these high certification rates could have important effects on temperate reefs, particularly if concentrated in small areas.

Divers can damage the environment by intentionally or accidentally holding, trampling, kicking, kneeling, or standing on benthic organisms (Ward[2] 1990, Hawkins and Roberts 1992). Most studies of the effects of these disturbances have been done on coral reefs. Talge (1990) followed divers on a coral reef and counted

[1] PADI (Professional Association of Diving Instructors). 1997. PADI Internet page: http://www.padi.com.

[2] Ward. F. 1990. Florida's coral reefs are imperiled. National Geographic, July:115-132.

how often they physically interacted with the reef. Twenty-six percent of divers observed had ≥1 interactions with corals and divers wearing gloves accounted for 72% of the interactions. In a study of the efficacy of visual fish surveys, Stanley and Wilson (1995) found that fish densities declined 41–77% in the presence of divers. Conversely, Cole (1994) found that divers attracted some species of fish by feeding them. Ward[2] (1990) questioned whether reef degradation is due to natural processes or damage inflicted by diving and other tourist activities. Tilmant and Schmahl (1981), however, were unable to detect clear patterns of damage linked to human usage on coral reefs in Biscayne National Park, Florida. Recently, Rouphael and Inglis (1997) found that diver damage was not a function of reef topography, but suggested diver disturbance may vary among different types of benthic assemblages.

Monterey Bay, California, known for its diverse subtidal forests of giant kelp, *Macrocystis pyrifera*, has long been an attraction for recreational divers. Because of accessibility and protection from swells, divers concentrate along a relatively small (2.8 km) section of coast between the Coast Guard Jetty in the city of Monterey and Lover's Point in the city of Pacific Grove. Saunders et al.[3] (1997) report that an estimated 65,000 diver days are spent annually in this region. The environment of heavily used dive sites like this may be impacted by SCUBA diving and these impacts may conflict with conservation goals (Davis and Tisdell 1995). While many events, both natural and anthropogenic, affect kelp forest communities, Saunders et al.[3] (1997) suggest that recreational diving impacts are minimal. However, we are unaware of any previous studies examining diver disturbance to kelp forest communities.

Estimates of the type and magnitude of diver disturbance to these communities would help guide future studies of the ecological effects of such disturbances as well as the design and management of marine protected areas where recreational SCUBA diving is allowed. We estimated this disturbance by following recreational divers underwater in southern Monterey Bay kelp forests and recording disturbances these divers caused to the subtidal environment.

METHODS

Diver disturbance was estimated during summer 1997. Dive sites surveyed were Breakwater Cove, Macabee Beach, and Lover's Point Cove, all in the vicinity of Cannery Row, a popular dive region in Monterey Bay. Randomly choosing which divers to follow was logistically difficult, so divers were selected haphazardly. With their permission, the 1st group of 2 or more divers making their shore entry concurrently with us were followed. Subjects were told we were "observing environments that divers like to explore" so they would not be startled by our presence or substantially alter their normal diving behavior. Observations started when divers

[3] Saunders, R., T.A. Okey, and J. Sobel. 1997. Recommendation for the establishment of the Edward F. Ricketts Marine Park. Center for Marine Conservation, San Francisco, California, USA.

were completely submerged, lasted for 20–30 minutes, and were standardized to 30 minutes.

Three categories of disturbance were recorded: number of contacts with the bottom, number of algal blades detached, and number of animals touched. A contact with the bottom was recorded if a diver purposely used the bottom for support with any part of the body, stirred up sediment with fins, or unintentionally contacted the bottom with any part of the body for >2 seconds. Any algal or seagrass blade or stipe detached from the bottom or from a larger plant by anything associated with the diver was recorded as an algal blade detached. Every animal touched by the diver or their equipment was recorded as an animal touched. Only contacts with obviously visible animals were counted. We also noted if the diver was part of a SCUBA instruction class.

To provide a broader perspective on diver disturbance, questionnaires were sent to diving officers with considerable experience in training divers associated with universities in the Pacific Northwest. Diving officers were asked to estimate how often divers of average skill unintentionally touched the bottom, stirred up sediment, or detached algal blades during a 30-minute dive in a kelp forest or bed.

Differences in disturbance between certified divers and divers in classes were examined using t-tests. For differences that were not significant, we estimated the power of the test to detect a true difference of the magnitude we observed, given our sample sizes (Zar 1984).

RESULTS

A total of 42 divers was observed for an average of 24.5 (SE = 0.4) minutes each. Standardized to a 30-minute interval, the average diver contacted the bottom 43.1 (SE = 3.8) times, touched 4.0 (SE = 0.6) animals, and detached 2.0 (SE = 0.4) algal blades. Divers in classes detached significantly more algal blades than certified divers ($t = 3.33$, $df = 40$, $P < 0.05$), but differences between these 2 groups for other disturbances were not significant (t-tests, $P > 0.05$) (Table 1). Power analyis indicated that the probability of detecting a true difference in contacts with the bottom of the size we observed (41.0–49.1 = –8.1) was only 0.14 and for animals touched (difference of 1.8), the probablility was 0.30.

The estimates of diver disturbance by 4 diving officers who responded to the questionnaire were highly variable (Table 2). They estimated that in 30 minutes the average diver in kelp habitats would unintentionally contact the bottom 4–18 times, stir up sediment 12–120 times, and detach 0–3 algal blades. Unintentional contacts

Table 1. Observed disturbance by certified recreational divers and individuals in SCUBA classes. Data are mean number/30-minute dive (SE). * Significant difference ($P < 0.05$).

Disturbance	Certified divers (n = 31)	Class divers (n = 11)
Contacts with bottom	41.0 (3.2)	49.1 (11.8)
Animals touched	4.5 (0.7)	2.7 (1.0)
Algal blades detached	1.3 (0.6)	4.0 (1.0)*

Table 2. Diver disturbance estimated by 4 diving officers. Data are mean number/30-minute dive for average-skill-level divers.

Dive officer	Unintentional contacts with bottom	Displace sediment on bottom	Break kelp stipes
1	4	12	2
2	9	30	1
3	2–3	60–120	0–1
4	12–18	18–36	2–3

with the bottom and sediment disturbance were estimated separately in the questionnaire, but combined in our observations. Diving officers also reported observing occasional destructive behavior such as deliberate removal of plants and breaking kelp floats and noted that many recreational divers regularly handle subtidal animals.

The types of algal blades detached were most commonly those of the red algae *Chondracanthus* spp. (formerly *Gigartina)* and *Mazzaella* spp. (formerly *Iridaea*), surfgrass, *Phyllospadix* spp., (a flowering plant) and giant kelp (stipes broken). Of these, *Mazzaella* spp. appeared to be most resistant to diver disturbance, perhaps due to its thick blade with a relatively short and robust basal portion. The most obvious disturbance resulted from divers entangling themselves in giant kelp fronds and then purposely breaking the fronds to free themselves. Giant kelp fronds also frequently became wrapped around fins or tank valves without the divers' knowledge. Continued movement usually broke the stipe.

Animals touched included a variety of disturbances. Sea anemones, *Anthopleura* spp. and *Pachycerianthus fimbriatus*, were often touched forcefully until they retracted. Crabs, *Cancer* spp., *Oregonia gracilis*, *Pugettia* spp., and sea stars, *Asterina miniata*, *Astropecten* spp., *Henrichia* spp., *Orthasterias koehleri*, *Pisaster* spp., were picked up and dropped. Some divers attempted to feed or pet California sea lions, *Zalophus californianus*, and harbor seals, *Phoca vitulina*. Turban snails, *Tegula* spp., and top snails, *Calliostoma* spp., are abundant on giant kelp in the Monterey region (Lowry et al. 1974, Watanabe 1984). These snails were frequently swept from giant kelp blades by divers' fins.

We also observed, but did not quantify, other disturbances by divers during shore entry and exit. The olive snail, *Olivella biplicata*, is common in the gently sloping, sandy areas that are common diver entry and exit points in the Monterey region. These snails were frequently trampled and sediment resuspended. Diving officers also reported concern for rocky shore trampling during diver entry and exit.

DISCUSSION

Conservatively assuming a diver day is one 30-minute SCUBA dive/day, and that 65,000 diver days/year (Saunders et al.[3] 1997) is an accurate estimate of diving activity in the Monterey region, during 1 year recreational SCUBA divers contact the bottom approximately 2,800,000 times, touch animals 260,000 times and detach

130,000 algal blades. Most of this disturbance is concentrated in giant kelp forests along a 2.8 km section of coast. These estimates do not include disturbances to intertidal organisms during diver entry and exit, bottom disturbance caused by dive boat anchors, or detachment of giant kelp surface fronds and associated animals by the propellers of dive boats, and by divers attempting to swim on the surface through these fronds.

Sandy, protected areas that facilitate entry for divers are common habitats for the gastropod, *Olivella biplicata* (Ricketts et al. 1985). These snails commonly bury themselves in the sand during the day and forage at night. They are trampled and their habitat disturbed as divers enter and exit. Trampling may lead to mortality of *O. biplicata*, and resuspension of sediment in this habitat and in the subtidal may cause stress to other benthic animals (Rogers 1988, Neil 1990). We also noted stands of seagrasses, which are attached to the sand by rhizomes and shallow roots, being trampled during diver entry and exit.

These results and observations clearly indicate that recreational SCUBA diving causes a variety of disturbances to kelp communities. While these may be relatively minor on an individual basis, they may become ecologically important to the structure of these communities as increasing numbers of divers concentrate in small areas. Given the natural spatial and temporal variability of giant kelp forests (review in Foster and Schiel 1985), determining the ecological effects (and their generality) of diver disturbance would be difficult. Natural disturbances, particularly during El Niño events, can lead to the near elimination of giant kelp and associated understory algae (Dayton et al. 1992, Foster and Schiel[4] 1993). This does not mean, however, that diver disturbances are ecologically unimportant. These disturbances represent unnatural events, the effects of which are added to natural disturbances. Moreover, assuming recreational diving is more frequent during the spring and summer, the majority of diver disturbances occur when kelp forest communities in central California are recovering from the effects of natural disturbances such as storms (Foster and Schiel[4] 1985).

Increasing disturbance to the marine environment is inherent to the growth of SCUBA diving. Davis and Tisdell (1995) refer to SCUBA diving as an "activity which is making increasing demands on marine resources." Responses from dive officers and our observations in other areas indicate that diver disturbances are not unique to the Monterey region. They are, however, more likely to become an issue in areas where diving is offered as a major tourist attraction.

As recreational SCUBA diving in kelp communities increases, our data suggest more attention should be given to managing its environmental effects, particularly in areas such as parks and refuges that often attract and encourage diving as an outdoor activity.

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[4] Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: A community profile. USDI Fish and Wildlife Service, Biological Report 85, Washington, D.C., USA.

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REPRODUCTION IN THE RED DIAMOND RATTLESNAKE IN CALIFORNIA

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The red diamond rattlesnake, *Crotalus ruber*, ranges from southwestern California (northeast of San Gorgonio Pass) and the Riverside area, southward through Baja California (Stebbins 1985). Information on mating time and number of young for the red diamond rattlesnake are given in Klauber (1972). The purpose of this note is to present information on timing of the testicular cycle and to provide additional litter sizes.

Data are presented from 43 sexually mature red diamond rattlesnakes (28 males: mean snout-vent length [SVL] = 813 mm ± 130.3 SD, range = 637–1180 mm; 15 females: mean SVL = 813 mm ± 86.6 SD, range = 662–960 mm) from the herpetology collection of the Natural History Museum of Los Angeles County (LACM) (Appendix A). Snakes were collected from 1935 to 1977. With the exception of 2 snakes from Orange County, which were collected from the coastal slope (winter-dominated rainfall), most of the remaining snakes came from the desert of Riverside County (summer-dominated rainfall). However, as the snakes were collected in different years with varying amounts of rainfall, it is not possible to discuss the effects of precipitation on their reproductive cycle.

Counts were made of enlarged follicles (>10 mm length). No females containing oviductal eggs were present. The left ovary was removed from females and the left testis, vas deferens, and part of the kidney were removed from males for histological examination. Tissues were embedded in paraffin and cut into 5-μm sections. Slides were stained with Harris' hematoxylin followed by eosin counterstain. Testis slides were examined to determine the stage of the male cycle; ovary slides were examined for the presence of yolk deposition (*sensu* Aldridge 1979a). Vasa deferentia were examined for sperm. Slides of kidney sexual segments were examined for secretory activity.

Not all tissues were available for histological examination due to damage or autolysis, but the following were examined: 9 ovaries, 28 testes, 25 kidneys, 16 vasa deferentia.

Testicular histology was similar to that reported by Goldberg and Parker (1975) for the striped whipsnake, *Masticophis taeniatus*, and gopher snake, *Pituophis catenifer* (= *P. melanoleucus*), and by Johnson et al. (1982) for the cottonmouth, *Agkistrodon piscivorus*. In the regressed testes, seminiferous tubules contained spermatogonia and Sertoli cells. In recrudescence, there was renewal of spermatogenic cells characterized by spermatogonial divisions; primary and secondary spermatocytes and occasional spermatids were present. In spermiogenesis, metamorphosing

spermatids and mature sperm were present. Males undergoing spermiogenesis were found only in August (Table 1); regressed testes were found in February–May. Males with testes in recrudescence were found in April–August. The smallest mature male (sperm in vas deferens) measured 637 mm SVL. To avoid bias from including immature males in analysis of the testicular cycle, males smaller than this size were excluded from the study.

While small sample sizes prevented a definitive description of the testicular cycle, the presence of 19 males with regressed testes in winter–spring (February–May) and 2 males undergoing spermiogenesis in August suggests the red diamond rattlesnake undergoes an aestival spermatogenesis (*sensu* Saint Girons 1982) in which spermiogenesis ends in September–October. The timing of events in the testicular cycles of other North American rattlesnakes fit this pattern (Aldridge 1979b; Jacob et al. 1987; Goldberg 1999a, b). Because the red diamond rattlesnake is active mainly during spring in southern California (Klauber 1931), obtaining more late summer–autumn males to examine for spermiogenesis would be difficult.

Histological examination of the vasa deferentia revealed sperm present in the following proportions: February, 1/1 (100%); March, 2/2 (100%); April, 7/7 (100%); May, 3/3 (100%); June 1/1, (100%); July, 0/1 (0%); August, 0/1 (0%). This suggests this species has the potential to breed during spring using sperm stored over winter in the vasa deferentia. Red diamond rattlesnake mating has been observed in the wild in March and April (Klauber 1972). Additional field observations will be needed to ascertain if breeding is restricted to spring or whether some occurs in autumn. Histological examination revealed secretory granules in the enlarged sexual segment of the kidney in the following proportions: February, 1/1 (100%); March, 3/3 (100%); April, 10/10 (100%); May, 6/6 (100%); June, 1/1 (100%); July, 1/1 (100%); August, 1/3 (33%). Mating coincides with hypertrophy of the kidney sexual segment (Saint Girons 1982).

The smallest reproductively active female red diamond rattlesnake measured 662 mm SVL (enlarged follicles >10 mm length). Females smaller than this size were excluded from the study to avoid including immature females in analysis of the ovarian cycle. Females with enlarged follicles (>10 mm length) were found March–June and in September (Table 2). It is likely the March–June females would have ovulated and produced young later that same year. The 1 September female with enlarged

Table 1. Monthly distribution of conditions in seasonal testicular cycle of red diamond rattlesnakes from southern California. Values shown are the numbers of males exhibiting each of the 3 conditions.

Month	n	Regressed	Recrudescence	Spermiogenesis
February	1	1	0	0
March	3	3	0	0
April	11	9	2	0
May	7	6	1	0
June	2	0	2	0
July	1	0	1	0
August	3	0	1	2

follicles probably would have ovulated the next year. Females typically begin yolk deposition in 1 reproductive season and complete it the next year, following a biennial reproductive cycle which has been reported for other North American rattlesnakes (Rahn 1942; Tinkle 1962; Goldberg 1999a, b). Additional female red diamond rattlesnakes will need to be examined to ascertain whether this species has a biennial reproductive cycle. Only 7/15 (47%) of the females showed evidence of reproductive activity. This is somewhat higher than the 35% exhibited by tiger rattlesnakes, *Crotalus tigris* (Goldberg 1999a), and the 25% exhibited by blacktail rattlesnakes, *C. molossus* (Goldberg 1999b).

Mean litter sizes estimated from counts of enlarged follicles (>10 mm length) from 7 red diamond rattlesnake females was 6.3±1.5 SD, range = 4–8 (Table 3). This value may be higher than what actually occurs as some of the counted enlarged ovarian follicles may not have completed their development. The mean for 43 red diamond rattlesnake litters (= broods) from Klauber (1972) was 7.6±3.8 SD, range = 3–20. The difference between these means was not significant t = 0.92, df = 48, $P > 0.30$). Both mean values put the red diamond rattlesnake slightly below the 8–10 per litter reported for "our commonest and most important species of rattlesnakes found in the United States" by Klauber (1972:734).

While useful information on reproduction can be obtained through histological examination of museum specimens, additional field studies will be required before all aspects of red diamond rattlesnake reproductive biology are known.

Table 2. Monthly distribution of conditions in seasonal ovarian cycle of red diamond rattlesnakes from southern California. Values shown are the numbers of females exhibiting each of the 2 conditions.

Month	n	Inactive	Enlarged follicles (>10 mm length)
March	1	0	1
April	4	2	2
May	5	3	2
June	2	1	1
July	1	1	0
August	1	1	0
September	1	0	1

Table 3. Litter sizes for red diamond rattlesnakes from southern California estimated from counts of enlarged follicles >10 mm length.

Date	SVL(mm)	Litter size	County	LACM #
March 20	809	6	Riverside	105011
April 16	820	8	Orange	28021
April 29	960	6	Riverside	105024
May 26	890	7	Riverside	105033
May 27	927	8	Riverside	52560
June 17	662	4	Riverside	105014
Sept 25	863	5	Riverside	105036

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Appendix A. Specimens of red diamond rattlesnake examined from the herpetology collection of the Natural History Museum of Los Angeles County.

Orange County: 28021, 52564

Riverside County: 3040, 20015, 20016, 28022, 52560, 63445, 105003, 105004, 105006, 105007, 105010-105015, 105017-105020, 105023, 105024, 105026, 105028, 105030, 105033-105036, 116022, 116023, 122109, 122110, 126080, 126225, 134041, 138224

San Diego County: 3044, 20007, 20011, 28020

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FIRST REPORTED OCCURRENCE OF *OPHIDASCARIS LABIATOPAPILLOSA* (NEMATODA: ASCARIDIDAE) IN THE RED DIAMOND RATTLESNAKE

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The red diamond rattlesnake, *Crotalus ruber*, occurs from southwestern California (northeast of San Gorgonio Pass) and the Riverside area, southward through Baja California to Cabo San Lucas (Stebbins 1985). An extensive review of the literature revealed only 1 report of helminth parasites in this snake, that of Mankau and Widmer (1977) who found cestode larvae, *Mesocestoides* sp. This paper reports an additional helminth parasite, the ascarid nematode *Ophidascaris labiatopapillosa*, in the red diamond rattlesnake.

Fifty-nine *C. ruber* from the Natural History Museum of Los Angeles County (LACM) previously collected from 4 California counties (Riverside, 45; San Diego, 11; Orange, 2; San Bernardino, 1) were examined for helminths. A mid-ventral incision was made through the body wall and organ surfaces in the posterior portion of the body cavity were visually checked for helminths. Four nematodes were found embedded in the coelomic fat bodies of LACM # 105034, which was collected on 5 May 1960 in Riverside County, 6 km N of Whitewater on Whitewater Canyon Road, 490 m elevation (33°58'N, 116°39'W). These were the only helminths found in the red diamond rattlesnakes examined.

Nematodes were removed from the fat bodies, cleared in glycerol for several days on a microscope slide, placed under a coverslip, and examined at 100X using a compound microscope. Based upon Hartwich's (1974) key and the paper by Ash and Beaver (1963), the 1 male and 3 immature female nematodes were assigned to *O. labiatopapillosa*. Prevalence of infection (number infected snakes/number snakes examined) was 1/59 (2%). Voucher specimens were placed in a vial of 70% ethanol and deposited in the United States National Parasite Collection, Beltsville, Maryland as USNPC # 89173.

Thirty-one species have been assigned to the genus *Ophidascaris* (Baker 1987). Of these, only *O. labiatopapillosa* is known to occur in the United States and has been reported from the eastern racer, *Coluber constrictor*, and the common kingsnake, *Lampropeltis getula*, from Florida; the plainbelly water snake, *Nerodia erythrogaster*, from Alabama; the eastern hognose snake, *Heterodon platirhinos*, and the Mississippi green water snake, *Nerodia cyclopion*, from Louisiana; the northern water snake,

Nerodia sipedon, from Michigan; and the yellowbelly racer, *Coluber constrictor flaviventris*, from Texas (Ash and Beaver 1963, Detterline et al. 1984). The red diamond rattlesnake is a new host record and the first report of a viperid snake to harbor *O. labiatopapillosa*. California is a new locality record.

Walton (1937) found larvae of *O. labiatopapillosa* encysted in the stomach wall, mesentery and muscles of 4 amphibians in Florida: three-toed amphiuma, *Amphiuma tridactylum*; gopher frog, *Rana capito*; bullfrog, *R. catesbeiana*; and Florida leopard frog, *R. sphenocephala*. Snakes (the diamondback water snake, *Nerodia rhombifer*, and northern water snake) given larvae of *O. labiatopapillosa* taken from the above ranids contained mature and immature nematodes when examined 4 weeks postinfection (Walton 1937). The intermediate host for *O. labiatopapillosa* in California is presently unknown.

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We thank D. Kizirian (LACM) for permission to examine red diamond rattlesnakes.

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IN MEMORIAM

IRENE TIMOSSI (1951–1998)

California's wildlife biologists lost a remarkable colleague on 29 December 1998 when Irene Timossi passed away from breast cancer at her San Rafael home. Irene was the consummate wildlife professional working to advance knowledge and conserve California's precious biological resources. Irene was instrumental in educating many graduate students and staff at the University of California, Berkeley, Department of Environmental Science, Policy, and Management and other wildlife biologists about computers, data analysis, California natural history, and good food. She was born Irene Clara Wright in Van Nuys, California on 5 May 1951. She grew up near Tujunga Canyon where her hikes in the chaparral-covered hills set her life's course working to conserve and understand California's natural history. She received a B.A. degree in environmental biology with an emphasis on botany from the University of California, Santa Barbara in 1973. In 1977, Irene took computer programming courses at Marin Community College, which led to work as a systems analyst with the Bank of America and Levi Strauss. She received an M.S. degree in wildland resource science from the University of California, Berkeley in 1985. Irene was a long-time member of The Wildlife Society and Cooper Ornithological Society.

Her unique combination of skills in wildlife and computers gave her the opportunity to work as a systems analyst specializing in natural resource issues. In August 1982, Irene began her lifelong association with the University of California, Berkeley, where she worked for faculty and graduate students as a research assistant, programmer, and analyst. She also worked with the Point Reyes Bird Observatory, the California Department of Fish and Game, and Pacific Gas and Electric Company. She published many scientific papers. Her most significant professional contributions included her programming and database development for the California Wildlife Habitat Relationships System and co-authoring the book "Plant Communities of Marin," published by the California Native Plant Society. Irene's spare time was spent birding, botanizing, and SCUBA diving throughout the world. Her calm, quiet demeanor made her a pleasure to work with, and Irene's great insight and creativity led to solutions to problems that escaped many of her colleagues. She is survived by her husband, Christopher Timossi, whom she married on 9 October 1976 in San Anselmo. Her ashes were spread under a favorite stand of madrones on her birthday, 5 May 1999. She is dearly missed by all who knew her.

–*Christopher Timossi*, San Rafael, California
–*Barrett A. Garrison*, California Department of Fish and Game, Sacramento, California
–*Reginald H. Barrett*, University of California, Berkeley, California.

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